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S. Kadowaki, T. Kasedo, T. Nakazono,
Y. Yamashita, and H. Hirata

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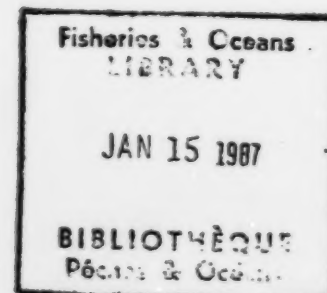
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The Relation between Sediment Flux and Fish Feeding
in Coastal Culture Farms*¹Shusaku KADOWAKI*², Teruo KASEDO*², Tsurayuki NAKAZONO*²,
Yaoki YAMASHITA*³ and Hachiro HIRATA*⁴

Abstract

Sediment flux in coastal culture farms was observed in order to estimate an environmental load resulting from fish feeding. Observations were made 63 times, between October 1977 and February 1980, in the farms located around the Fisheries Research Laboratory of Kagoshima University.

The sediments were collected from 3 stations: St. 1 in a sea bream farm, St. 2 in a yellow-tail farm, and St. 3 in a non-culture area. Water depth in the St. 1, 2, and 3 were: 8 to 12 m, 14 to 16 m, and 12 to 13 m, respectively. Polyethylene columns, 5 liters capacity with 17 cm opening, were set on the sea bottom at each station, and renewed every 4-days during the culture seasons. The samples were filtered after collection, and dried at 60°C for 5 days. The food quantity and quality were noted every day in each farm.

Average daily amounts of sediments in St. 1, 2, and 3 were calculated to be: 33.8, 23.0, and 14.6 g/m², respectively. The sedimentations were related to the amount of foods supplied, and to water depth. Some diffusion of biodeposits was observed in a deeper farm. The type of food supplied also affected the amount of sediment flux. The amounts of sediments ranged from 4.1 to 5.9 g/m² when the fish were fed daily on 1202 kg of fresh anchovies, but such amounts increased about 4 times, 17.0 to 21.6 g/m², when 1247 kg of frozen mackerel were supplied.

- *¹ (Contribution No. 14 from Fish. Res. Lab., Fac. Fish., Kagoshima Univ.).
- *² (Fish. Res. Lab., Fac. Fish., Kagoshima Univ., Azuma-cho, Izumi-gun, Kagoshima, 899-14 Japan).
- *³ (Yamashita Fish. Co. Ltd., Azuma-cho, Izumi-gun, Kagoshima, 899-14 Japan).
- *⁴ (Lab. Fish Cultivation Physiol., Fac. Fish., Kagoshima Univ., Kagoshima, 890 Japan).

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Research about fish farming in shallow waters and auto-pollution was taken as a topic at the 1977 spring convention of the Japanese Society for Scientific Fisheries. We see from the collected lectures that many reports have already been produced. However, about the main topic which is the relationship between the volume of sediment and the volume of feed as well as the feed quality, the analyses are still insufficient. Regarding the relationship between the amounts of feed and volumes of sediment, Hagino (1977) compiled the results of tests conducted in tanks at the Wakayama and at the Kochi Fisheries research centers. The data from each center are, however, still few.

The main reason for the few data about the volumes of feed and of sediment is that it is extremely difficult to gather data at the farming grounds. More particularly, the difficulty of knowing the precise amounts of feeding at the site is a well known fact. Fortunately a large-scale shallow farming ground is extending in front of this fisheries research center and since 1977 it has been possible to the farm operators and to this research center staff to carry out research in common. We were therefore able to establish the correlation between the volumes of sediment, of feeding and the feed quality.

As research on sediments accompanying fish farming is a relatively recent field, the terminology is still unsettled (Hagino 1977; Hata 1979, Koyama 1975, Tanaka 1977). So we decided to call "sediment flux" the volume of sediment precipitation for one day per unit area, and expressed its unit as $\text{g/m}^2 \cdot \text{day}$.

The present study was commissioned by the Azuma town's council, the Kagoshima Prefecture, by the Azuma Fisheries Cooperative and by

the National Seawater Fish Farming Association. We thank all those involved for their support. We also thank Professor Akira FUJI of the Hokkaido University and Dr. Keiyo TANAKA of the Kagawa University for their kind advice. We express also our thanks to Akihiko SHINOMIYA, instructor at this department, and to Mr. Ko YAMASHITA of the Yamashita Fisheries Co. for their kind cooperation.

Survey method

According to the classification made by INOUE et al (1970), the presently surveyed fishing ground is a typical fish farm using a small channel. The variations of the tide moving back and forth between the East China Sea and Yatsushiro Sea are strong and the current in the vicinity of the fish cages reaches often 1-2 kt. As shown in Fig. 1, the area of the present fish farm is roughly 10 ha, and about 300 cages (mainly $7 \times 7 \times 5 \text{ m}^3$) are floating at this site. The annual production of this fish farm is estimated at more or less 400 t.

We surveyed three sites viz. a cluster of cages for the rearing of red seabream (St. 1; a-c), a cluster of cages for the rearing of yellowtail (St. 2; a-c) as well as a non-farming fishing ground located about 500 m away from the above cage clusters (St. 3; a or b). The depth at St. 1 is 8-12 m and thus relatively small. At St. 2 and St. 3, the depths are 14-16 m and 12-13 m respectively. As for the survey of St. 3, we operated at the point a until December 1977, and thereafter at the point b (Fig. 1).

To gather the sediments, we followed the method of Kadowaki et al (1978). That is, we suspended 25 cm long cylindrical polyethylene containers with a 17-cm opening by means of floaters and weights 60-80 cm from the sea floor, collected almost every 4 days the sediment gathered

inside the container, filtered the sediment with No. 2 filter paper, and weighed carefully after heating for 2 days at 60°C. The feeding and the quality of the feed were recorded daily for each cage group during the survey period.

From October 1977 to February 1980, the survey was conducted intermittently. In all, we operated 63 times on 285 days. From March to May in the spring, the fish cages are replaced and moved so that no survey was possible during that time. For 3 years we performed regular surveys every four days during the maximum feeding period of October-December.

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Results and discussion

Table 1 shows all the data of the surveys. On the basis of Table 1, we found the respective 3-point displacement average values of the feeding volume and the sediment flux. In Fig. 2 we showed these correlations by St. (by water depth). Although the relationship between the volumes of feed and the sediment flux shows scattering for all stations, we saw a rough positive correlation in all cases (at St. 1, $r = +0.49$ and at St. 2, $r = +0.58$).

As the Fig. shows, the slope at St. 1 (red seabream cage cluster) is relatively steep while at St. 2 (yellowtail cages), the slope tends to be gentle. Rather than being due to the species of fish, the difference is due to the fact that while the water depth at St. 1 is rather small with 8-12 m, it is 12-16 m at St. 2 and there seems to be a wider dispersion of suspended matters where the depth under the cage cluster is greater.

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As indicated in the bottom column of Table 2 which gives the sediment flux per 1 t of feeding, a-c of St. 1 shows always an average

value of 28.9 dry $\text{g}/\text{m}^2 \cdot \text{day}$. In a-c of St. 2, the average was 13.6 dry $\text{g}/\text{m}^2 \cdot \text{day}$. If basing ourselves on the instance of rotifer rearing by Yamauchi (1979), we make the dry-wet conversion, we obtain 444.5 wet $\text{g}/\text{m}^2 \cdot \text{day}$ for St. 1 and 209.2 wet $\text{g}/\text{m}^2 \cdot \text{day}$ for St. 2. So, the rates of sediment flux (wet weight) per 1 t of feeding in St. 1 and in St. 2 are about 30 and 15% respectively.

Hagino (1977) states that the feeding volume-sediment flux ratio in mid-bay fish farms is about 10%. However, in the channel-type fish farm such as the ones studied in this survey, relatively higher values were obtained. These differences seem to be due to differences in dispersion concomitant to such conditions as depth.

Meanwhile the sediment flux at the non-rearing fishing ground St. 3 removed about 500 m from the fish cage clusters showed an average of 14.6 dry $\text{g}/\text{m}^2 \cdot \text{day}$ throughout the entire period. This value is about half of the values obtained at the fish farms of St. 1 and St. 2 (Table 1). These facts mean a dispersion of floating and suspended matters from the fish farms to the non-farming fishing grounds. One should make additional surveys taking into account factors such as depth and currents.

Table 2 shows the seasonal variations of the sediment flux at the fish farms. The average is highest in the fall from September to November, with 36.7 dry $\text{g}/\text{m}^2 \cdot \text{day}$. For the winter (Dec.-Jan.) and the summer (June-July), the average is 45% lower than in the fall. The average was 16.4 dry $\text{g}/\text{m}^2 \cdot \text{day}$. The observed high sediment flux in the fall seems to correspond to the maximum feeding taking place at that time.

One noteworthy point is that the sediment flux depends on the type of feed. As Table 1 shows, frozen mackerel was given from June 6

to June 26, 1978. From the following 27th to July 13, the feed consisted in fresh anchovies which had just been caught. The difference in sediment fluxes between these 2 types of food is obvious and we compiled the average values in Table 3. The amounts of both feeds per day were about equal at 1,200-1,300 kg/day. While the average sediment flux was 17.0-21.6 dry g/m²·day during the frozen mackerel feeding period, it was only 4.1-5.9 dry g/m²·day viz. $\frac{1}{4}$ this volume when feeding the fish fresh anchovies. The volume was thus extremely small. These fresh anchovies had been caught by the operators and one may say that the difference in feed quality and excellent freshness contributed to bring down the sediment flux. One might consequently appreciate the fact that if fish farmers can secure feed by themselves, ideal conditions for fish farming in shallow waters will be obtained.

Recent studies about sediments in the sea are not merely related to fish farming (Nitta 1980, Tanaka 1977). We notice new topics in the fields of marine physics and chemistry (Handa 1979; Hata 1979; Hirata et al 1979; Iseki et al 1980; Nishizawa 1966).

Handa wrote comprehensively about sediment traps (1979) and clarified various phenomena regarding sediments in the sea. Meanwhile, auto-pollution accompanying fish farming is studied carefully in connection with the red tide problem (Hanaoka, 1980; Nitta, 1980; Tahira, 1978). Thus the importance of research about bottom sediments in the sea increases from both the viewpoints of natural and of social sciences. In the future we wish to pursue our surveys of the bottom sedimentation mechanism and of the state of dispersion at the fishing grounds while referring ourselves to the present results and to the continuous DO recording data by cruising in fish farming grounds.

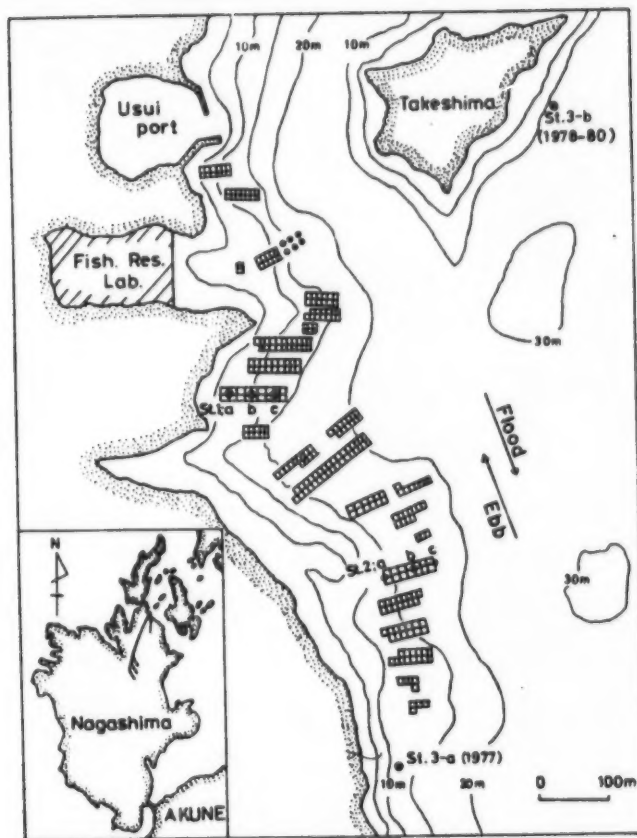


Fig. 1. Map showing the experimental stations in a coastal fish farm with isobath.

Table 1. Daily amount of sediment flux and food supplied.

Item		SEDIMENT (<i>dry g/m²·day</i>)							FOOD (<i>kg dry</i>)	
Farm		Sea bream (St. 1)			Yellowtail (St. 2)			Out of farm		
Substation		a	b	c	a	b	c	(St. 3 a or b)	Sea	Yellow-
Depth		8 m	10 m	12 m	14 m	15 m	16 m	12~13 m	bream	tail
1977										
Oct.	13-17		47.5	—	23.2	61.9	67.2	36.5	1770	1120
	17-21				32.1	59.7	39.8	21.0	1010	2240
	21-25				44.2	58.6	49.7	24.3	760	1370
	25-29		51.9	—	45.3	84.0	32.1	18.8	760	1370
	29-2		65.2	—	33.2	22.1	32.1	17.7	1590	1360
Nov.	2-7		59.7	—	44.2	19.9	24.3	24.3	3850	2430
	7-11		47.5	—	51.9	32.1	26.5	30.9	1010	1530
	11-15		40.9		47.5	24.3	28.7	37.1	840	2970
	15-19		36.5	—	34.3	26.5	29.8	21.0	1460	1440
	19-24		22.1		45.3	18.8	19.9	14.4	2080	1150
	24-28		16.6		51.9	25.4	28.7	16.6	1390	2870
Dec.	28-2		18.8		37.6	18.8	11.1	15.5	1130	1260
	2-7		19.5	—	32.1	13.3	12.2	11.7	540	920
	7-12		23.2	—	19.9	14.4	12.2	13.9	1020	430
	12-16		21.0	—	18.8	17.7	14.4	19.4	530	1670
1978										
June	6-10	11.1	19.5	9.5	18.9	15.5	14.3	16.5	980	850
	10-14	20.8	21.3	15.3	10.0	9.2	6.0	5.8	1950	1030
	14-18	22.7	48.0	45.3	19.6	23.2	27.9	9.5	750	1090
	18-22	20.8	32.4	21.0	21.4	20.0	19.8	15.8	1240	2360
	22-26	13.7	12.0	10.7	14.7	17.1	17.2	20.1	980	1240
	26-1	3.1	6.8	2.2	4.9	5.3	4.6	4.1	1510	1190
July	1-6	8.4	9.1	8.3	3.9	2.6	—	6.0	1560	720
	9-13	3.5	4.3	7.7	3.3	—	—	—	990	1240
Sep.	5-9	55.1	53.0	25.4	—	—	—	13.1	1050	
	9-13	68.4	32.6	35.3	—	—	—	11.8	1660	
	13-17	50.2	58.5	49.9	—	—	—	28.4	710	
	17-21	72.3	30.3	17.8	—	—	—	28.8	1500	
	21-25	42.5	52.6	12.2	—	—	—	23.0	1690	
	25-29	21.5	49.8	38.9	—	—	—	6.4	1800	
Oct.	3-7	57.6	93.3	53.1	—	—	—	28.1	1910	
	7-11	63.9	60.5	44.5	—	—	—	24.4	940	
	11-15	60.7	59.8	50.5	—	—	—	16.8	940	
	15-19	44.1	37.6	41.7	—	—	—	—	1500	

Table 1. (Continued)

Item		SEDIMENT (<i>dry-g/m²·dry</i>)						FOOD (<i>kg/day</i>)		
Farm		Sea bream (St. 1)			Yellowtail (St. 2)			Out of farm	Sea bream	Yellowtail
Substation	Depth	a	b	c	a	b	c	(St. 3 a or b) 12~13 m		
		8 m	10 m	12 m	14 m	15 m	16 m			
	19-23	38.0	54.0	31.2					1760	
	23-27	42.8	59.1	23.4				3.4	1880	
	27-31	25.4	70.7	42.7				19.6	1900	
	31-4	36.8	46.3	13.8				15.7	1800	
Nov.	4-8	33.4	57.8					6.7	870	
	12-16	22.2	42.1	64.3				5.5	1880	
	16-20	28.0	20.4	16.8				4.3	900	
	20-24	44.8						10.3	940	
	24-28	50.4	23.9	27.9				5.6	640	
	28-2	71.0	27.1	23.2				12.9	1120	
Dec.	2-7	70.9	21.8	11.6				10.8	730	
	7-11	30.5	30.0	14.8				9.3	480	
	14-18	11.8	17.3	7.0				6.9	560	
1979										
Oct.	8-12	31.5	49.1	46.8	13.1	9.6	4.4	5.1	580	1630
	12-16	31.5	31.0	22.2	44.4	39.8	22.8	6.3	1000	2830
	16-20	55.1	67.7	41.7	66.2	8.5	11.4	9.9	540	2310
	20-24	21.6	60.9	54.7	24.5	5.1	6.5	12.1	1200	3260
	28-1	19.3	101.7	17.6	3.6	12.8	11.2	9.8	990	4130
Nov.	1-5	12.1	51.9	52.5	19.5	11.7	11.4	11.4	480	4050
	5-9	19.9	67.4	13.5	22.9	9.4	18.8	17.8	1020	1990
	9-13	8.5	135.9	29.5	22.8	29.2	12.3	11.0	1110	4070
	13-17	21.8	53.6	43.7	9.8	41.3	15.5	16.8	1050	3380
	17-22	18.6	150.0	13.6	7.9	20.1	8.8	7.0	750	1550
1980										
Jan.	4-8	13.0	11.9	6.2	20.0	10.7	11.4	19.8	720	1130
	11-14	5.2	7.9	6.2	9.5	9.2	10.8	5.9	920	840
	14-17	14.0	31.0	17.6	15.8	12.6	14.8	15.0	680	800
	21-25	5.0	8.5	7.3	26.4	7.4	4.8	7.3	540	470
	25-29	25.2	11.4	19.3		67.8	10.1	9.2	680	660
	29-2	9.5	11.9	7.5		8.0	6.9	8.9	380	240
Feb.	2-6	8.6	7.6	14.5			9.9	10.0	840	300
mean		30.6	41.7	27.0	26.9	23.5	18.7	14.6	1147	1687
(a + b + c) ÷ 3			33.1			23.0		14.6	—	—
sediment: food			20.9			13.6		—	1000	1000

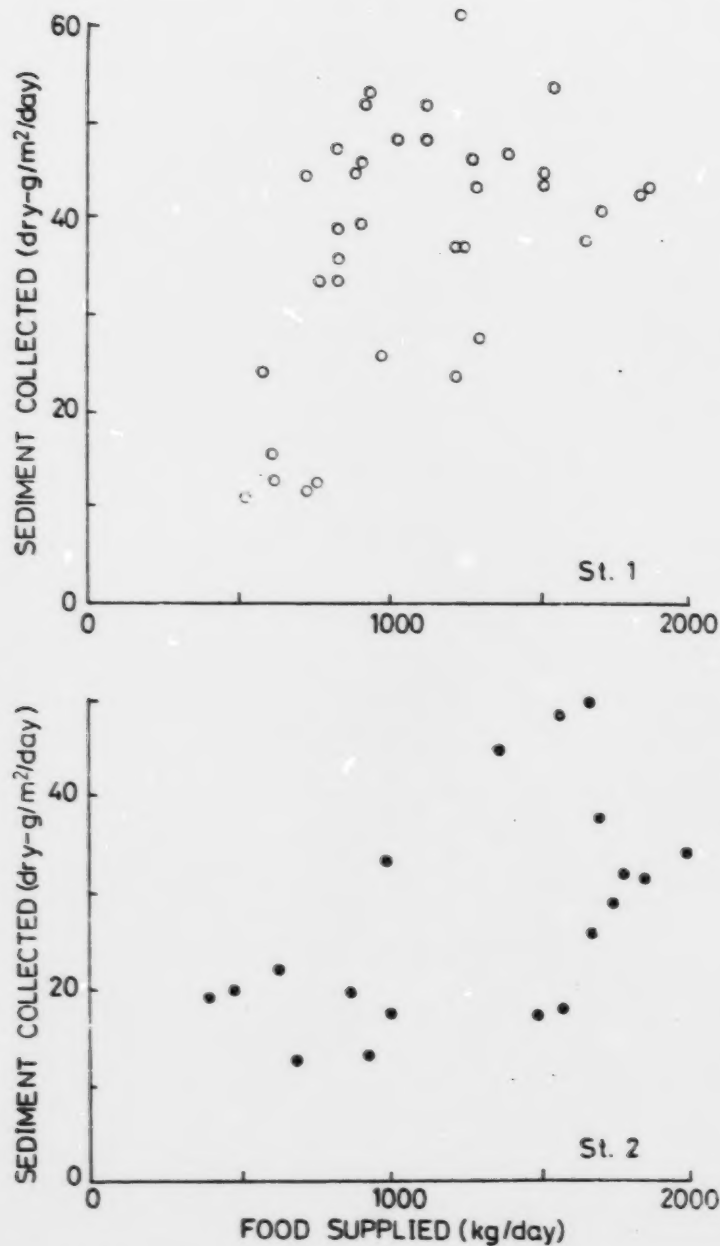


Fig. 2. Relation between daily amount of food supplied and sediment. Upper and lower diagrams show the results obtained from sea bream and yellowtail farms, respectively.

Table 2. Seasonal variation of sediment flux ($\text{dry-g/m}^2\text{-day}$) in different farm.

Season	Sea bream St. 1 (8-12 m)	Yellowtail St. 2 (14-16 m)	mean
Summer (Jun-Jul)	15.7	12.1	13.9
Autumn (Sep-Nov)	44.6	28.8	36.7
Winter (Dec-Jan)	19.8	17.7	18.8

Table 3. The amount of sediment flux influenced by food quality.

Type of food	Date	SEDIMENT ($\text{dry-g/m}^2\text{-day}$)		FOOD (kg/day)	
		Sea bream (8-12 m)	Yellowtail (14-16 m)	Sea bream	Yellowtail
Frozen mackerel	(June 6- June 26)	21.6	17.0	1180	1314
Fresh anchovy	(June 27- July 13)	5.9	4.1	1353	1050

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